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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 11 MISSION

ANOMALY REPORT NO. 2

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GLYCOL TEMPERATURE CONTROL VALVE

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MANNED SPACECRAFT CENTER
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GLYCOL TEMPERATURE CONTROL VALVE

STATEMENT

At various times during the Apollo 11 mission, the command module glycol temperature control valve failed to control the mixed water/glycol temperature to the required 45(±3)° F.

DISCUSSION

Normally for low radiator outlet temperatures, the glycol temperature control valve automatically maintains the evaporator inlet temperature between 42° and 48° F (fig. 1). As the radiator outlet temperature falls below 48° F, the glycol temperature control valve modulates open and allows hot water/glycol to mix with the colder water/glycol, thus maintaining the required evaporator inlet temperature. Conversely, as the mixed water/glycol temperature increases above 42° F, the valve starts to close and is completely closed when the evaporator inlet temperature rises above 48° F. When the mixed water/glycol is 42° F or less, the valve is fully open. The valve can also be operated manually by removing power from the control circuit.

Two effects of the anomalous valve operations were experienced during the mission. The first was noted during a portion of earth orbital flight as well as during most of the first 15 revolutions of the moon. As the temperature of the cold water/glycol returning from the radiators started increasing the temperature control valve failed to control, thus causing a premature increase in the evaporator inlet temperature. The most severe case occurred during revolution 14 when the valve did not close until the evaporator inlet temperature reached approximately 58° F (fig. 2).

The second effect of the anomalous operation occurred during revolutions 5, 13, and 15 (fig. 2) when the mixed water/glycol temperature decreased below 42° F. During revolutions 5 and 13, temperatures of 36° and 38° F, respectively, were noted before valve operation returned the temperature to the nominal control range. During revolution 15, an undershoot was observed (fig. 2). About this time, the temperature inlet switch was cycled from AUTO to MANUAL and back to AUTO and the evaporator outlet temperature began increasing from a low of 32° F until a temperature of 45° F was reached. During all subsequent mission phases, the glycol temperature control valve operated satisfactorily.

Analysis of flight data during the first effect of anomalous operation established that the valve did not stick in the maximum open position but only failed to modulate rapidly enough to prevent a premature increase in the water/glycol temperature.

Postflight testing demonstrated that the glycol temperature controller, which powers the temperature control valve, functioned properly and supplied correctly modulated pulses to the valve for a full range of input temperature signals. Corresponding valve response, however, appeared sluggish. Disassembly of the valve revealed that a bearing on the worm gear shaft in the actuator (fig. 3) had failed.

The valve has no electrical stops so that when it is commanded full open or closed, the motor drives the gear train into hard mechanical stops and stalls. Analysis showed that when the gear train is driven into the stops, the bearing is subjected to a total thrust load of 90 pounds. The bearing is rated for 20 pounds static thrust by the bearing manufacturer.

Examination of the bearing pieces showed that the sudden application of static thrust load at stall combined with poor boundary lubrication characteristics of the bearing lubricant resulted in fretting corrosion of the bearing race. The wear debris then accelerated the wear and eventually jammed one ball in the race, allowing the ball behind it to bend the ball retainer ear (fig. 3). When several of the ball retainer ears were bent out, the balls accumulated on one side and broke the ball retainer. Ball pressure then forced the shield out and the bearing disassembled itself.

Several identical valves have demonstrated acceptable performance after extensive life testing. One qualification test unit was subjected to 1300 hours of operation and wear patterns similar to those observed on Apollo 11 were noted, but no performance degradation was observed. Additionally, four qualification test units were subjected to simulated missions and accumulated from 635 to 1660 hours with no performance degradation, and one valve was successfully subjected to over 200 hours of ground testing with the bearing lubricant removed.

Finally, four units have been flown on Apollo 7 through Apollo 10 with no indication of performance degradation.

Analysis of the bearings from some of these units, however, revealed the same type of wear and that the units could eventually fail in the same mode.

If the temperature control valve should fail in flight, an existing malfunction procedure will be used to manually position the valve to approximately 35-percent bypass. This position will maintain a predetermined relationship between radiator outlet and evaporator outlet temperatures that only slightly increases overall system temperatures during periods of high heat loads.

CONCLUSION

The design allowed an application of loads which are beyond the rated capability of the bearing.

CORRECTIVE ACTION

Valve failure will not compromise future missions because by using an existing procedure the valve can be manually set at one position which will meet system requirements; consequently, no corrective action is required.

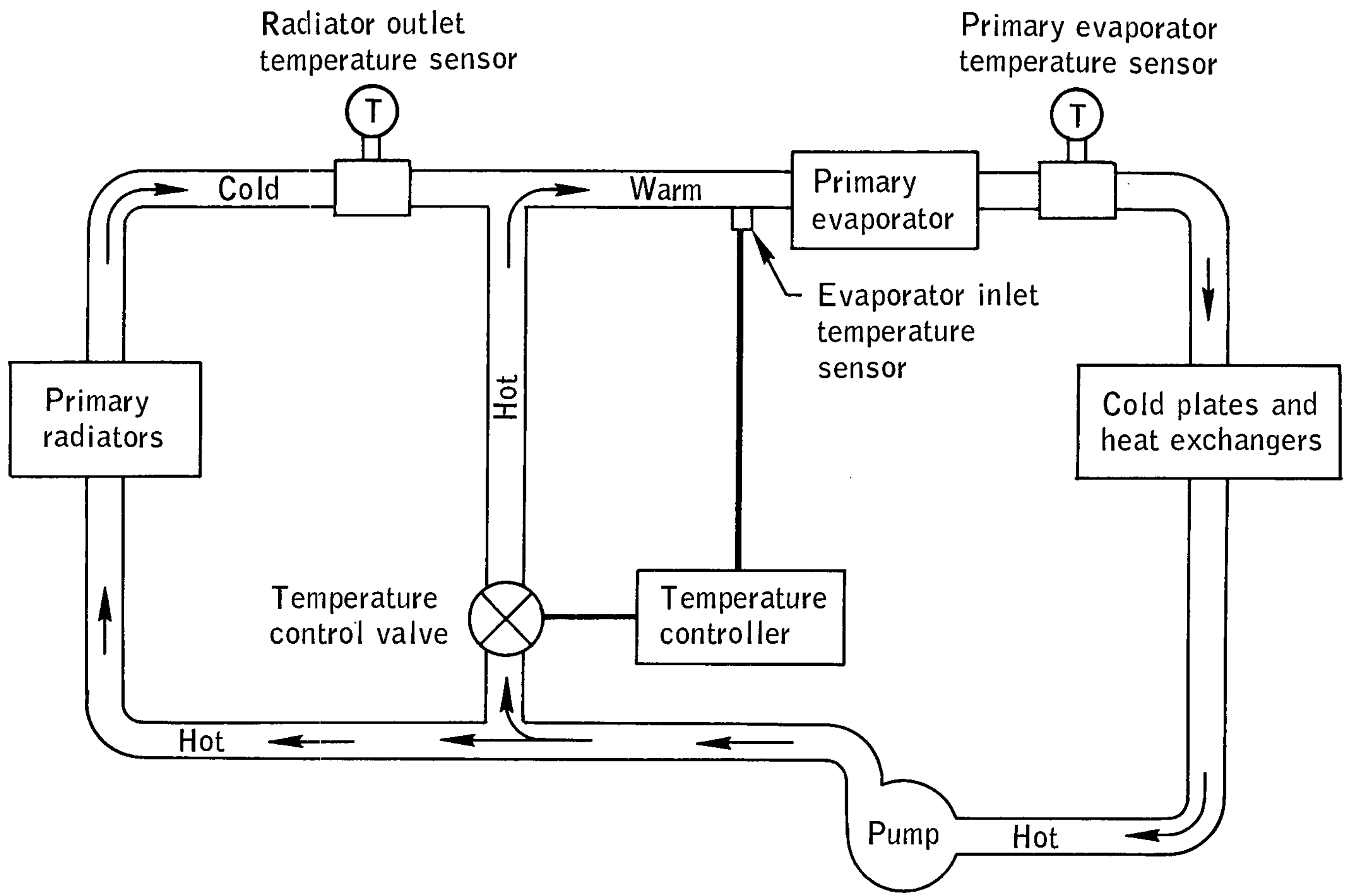


Figure 1.- Primary water/glycol coolant loop.

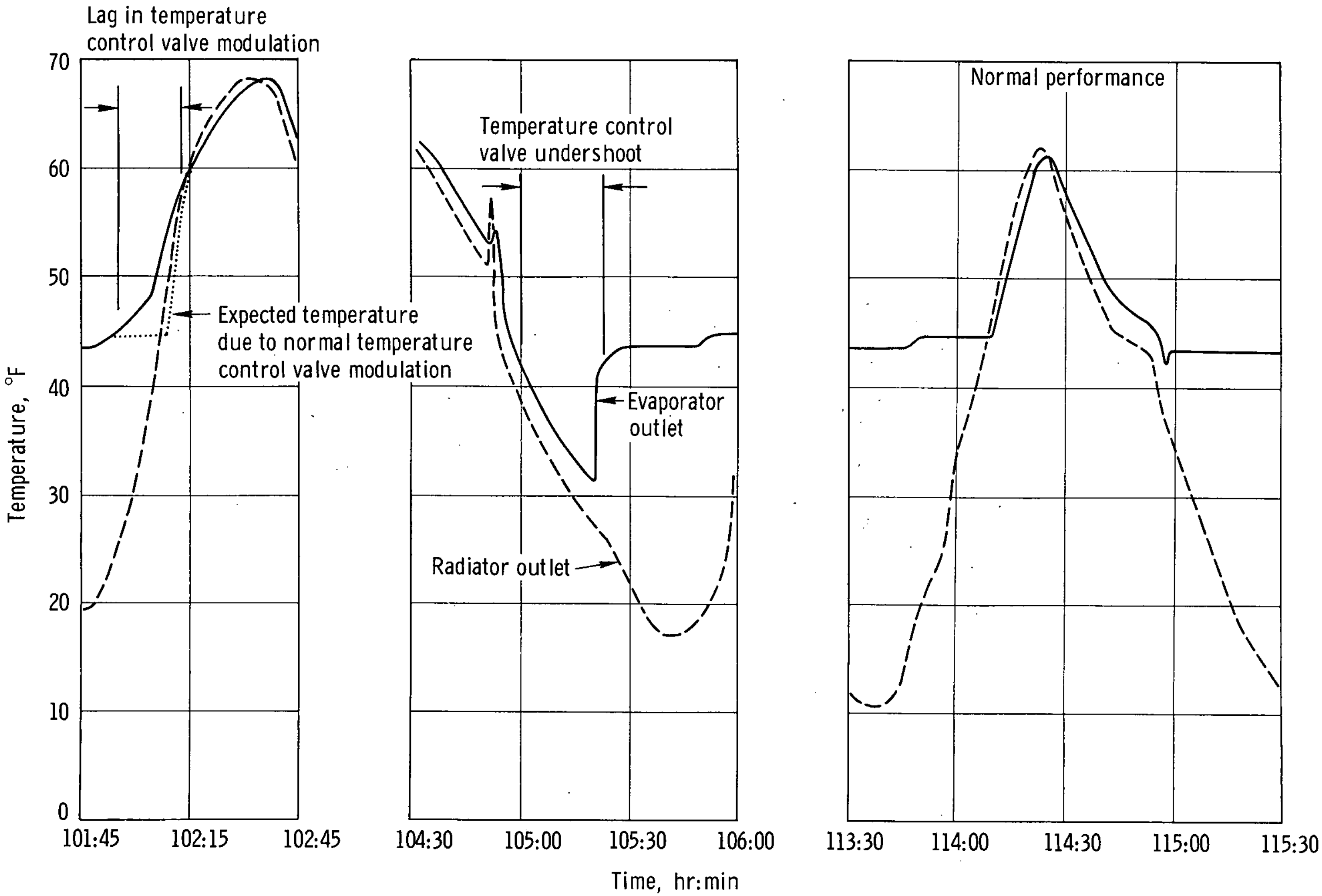
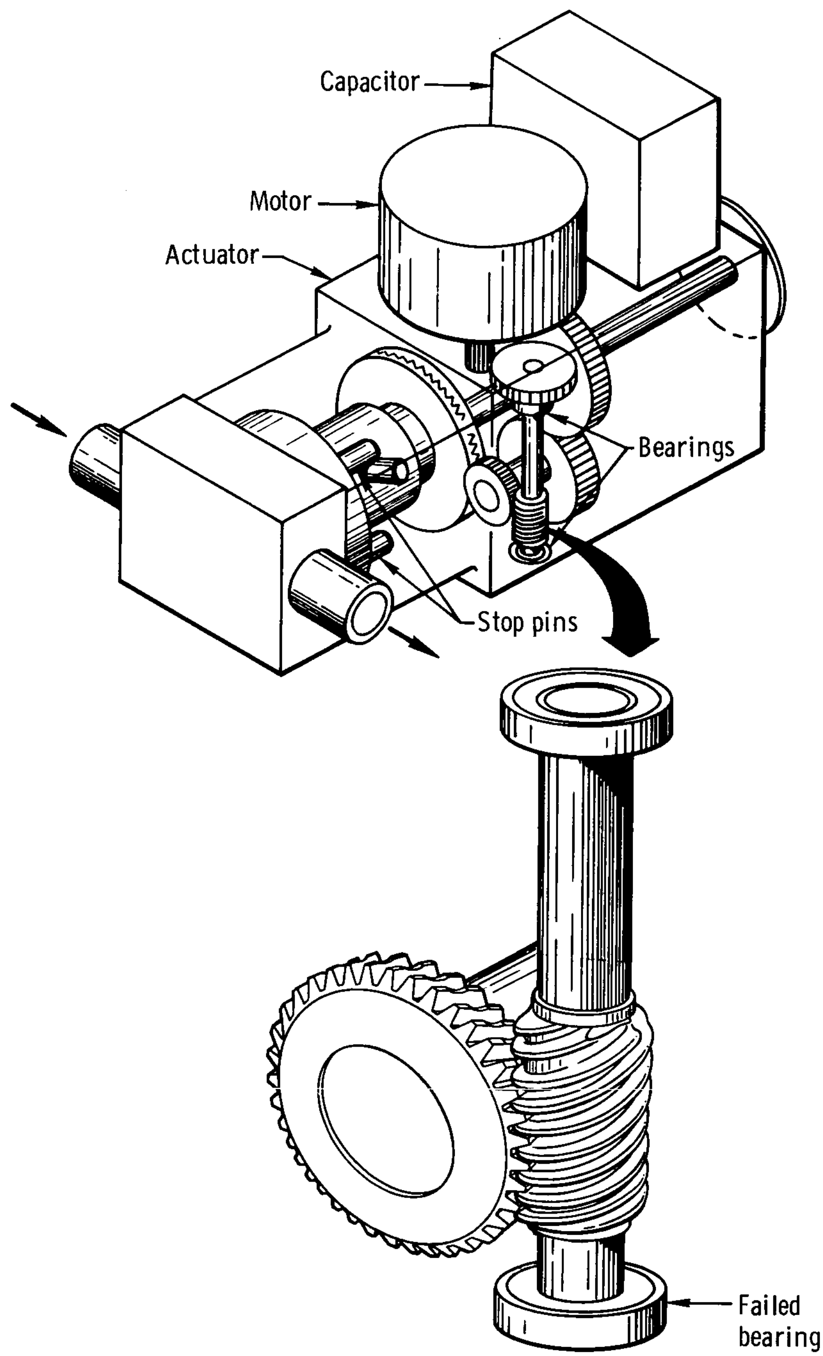


Figure 2.- Comparison of radiator and evaporator outlet temperatures.



(a) Location of failed bearing.

Figure 3. - Bearing assembly within temperature control valve.

(b) Failed bearing assembly.

Figure 3.- Concluded.

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